The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Design of Physics Research Laboratories

The proceedings of the symposium on the Design of Physics Research Laboratories, organized by the London and Home Counties Branch and held at the Royal Institution in November, 1957, will be published by Chapman and Hall Ltd., on behalf of the Institute, early in January. The papers presented at the conference are published in full together with an edited version of the discussion. The book is of 112 pages and includes 80 illustrations. The retail price is one guinea. Members of the Institute, in all grades, may purchase one copy for their *personal use* at the special price of fifteen shillings including postage. An order form is printed on page iii of this *Bulletin*. Orders, with remittances, should be sent direct to the Institute as soon as possible and preferably, except for overseas members, before December 31. All orders at the retail price should be placed through booksellers and should not be sent to the Institute.

Physical Society Exhibition

The Physical Society's 43rd Annual Exhibition of Instruments and Apparatus will be held in the halls of the Royal Horticultural Society, Westminster, London, S.W.1, from January 19-22, 1959, inclusive.

Members of the Institute who are not members of The Physical Society may obtain tickets for the Exhibition, available for any one day, on application to the Institute. A limited number of tickets for the members' session on the first morning are also available.

Orders for catalogues (price 6s. or by post 7s. 8d.) are not being handled by the Institute but should be sent, with remittances, direct to The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

Remission of Income Tax on Members' Subscriptions

Members are reminded of the announcement in the November *Bulletin* concerning the remission of income tax on subscriptions to the Institute. Those wishing to claim this relief must apply to their tax office for Form P358.

Committee on Grants to Students

It was announced in the September *Bulletin* that the Ministry of Education and the Scottish Education Department had set up a Committee on Grants to Students. The Institute has submitted evidence for the consideration of the Committee and this will be published in a later issue of the *Bulletin*.

Stress Analysis Group :
Delft Conference — Easter, 1959

The Stress Analysis Group in collaboration with the Instituut T.N.O. will hold a conference at the Technische Hogeschool, Delft, Netherlands, from March 31 to April 4, 1959. Authors from a number of European countries will present papers, preprints of which will be available before the conference. The conference is open to all interested but registration is necessary. Further details and registration forms may be obtained from the Secretary of the Institute.

Symposium on " Current developments in the production of high vacua "

The Institute is arranging a one-day symposium entitled " Current developments in the production of high vacua " to take place in London on April 17, 1959. There will be three sessions :—

(*a*) Chemical and ionic pumping in kinetic vacuum systems.
(*b*) Problems in the production of high vacua in large equipment.
(*c*) Analysis of residual gases in kinetic vacuum systems.

Each of the first two sessions will be opened by invited speakers, and offers of short contributions, especially for the third session, will be considered by the Organizing Committee if outlines are submitted by January 15 next.

The symposium is intended mainly for persons working with high vacua. Abstracts (but not preprints) will be circulated before the symposium, the proceedings of which will not be published in full.

Conference on " Some aspects of magnetism "

The Institute of Physics is arranging a conference on " Some aspects of magnetism " to take place in Sheffield from September 22-24, 1959. The subjects to be covered by the conference are:

(*a*) Fundamental theories of ferro-, ferri- and antiferro-magnetism, including magnetic structure.
(*b*) Theories of technical magnetization processes, including hysteresis, coercivity, anisotropy and directional effects.
(*c*) Theoretical and experimental studies of domain phenomena in bulk materials and thin films.
(*d*) Experimental and theoretical studies of antiferromagnetism in metals and non-metals.

Each session will be opened by an invited speaker and offers of other contributions should be submitted to the Secretary of the Institute before January 31 next. The conference is intended mainly for persons working in the field. Abstracts (but not preprints) will be circulated before the conference, the proceedings of which will not be published in full.

Payment of Subscriptions

Members are reminded that a form to be sent with remittances for 1959 subscriptions and for Journals at special rates will be included in the January *Bulletin*. They are asked not to send subscriptions until this form is issued.

List of Meetings for the Second Half Session

A full list of the meetings arranged by the Institute's Branches and Groups for the second half of the current session will be published in the January *Bulletin*.

Binding of the *Bulletin*

Members wishing to have their 1958 volumes of the *Bulletin* bound should send the twelve issues, with title page and index direct to F. J. Milner and Sons Ltd., Commerce Road, Brentford, Middlesex, enclosing a remittance for one pound made payable to the firm, and a sheet giving the name and address of the sender. A title page and contents list will be bound with each volume.

Title Page

The title page and contents list for the current volume has been distributed only to overseas members. Other members who would like copies should send a postcard to the Deputy Secretary but no request is needed from those who send their *Bulletins* for binding to the Institute's printers.

Binding of the Journals

Orders and inquiries about the binding of back-numbers of the *Journal of Scientific Instruments* and the *British Journal of Applied Physics* should now be sent direct to Messrs. E. A. Weeks and Son, 168 Gower Street, London, N.W.1 (EUSton 4674), and not to The Institute of Physics.

The price is twenty-three and sixpence post free (standard case).

Separate cases can be supplied for 15s. each.

Vol. 9, December, 1958

Electrodynamics

By GEOFFREY BUILDER, D.Sc., F.Inst.P.

(*School of Physics, University of Sydney*)

In his article on "The M.K.S. System" in the *Bulletin* of January, 1957, Professor Lipson issued a challenge for the production of "*a field theory in which the force between two current elements could be accepted as basic, in the same sense that the force between two charges or two magnetic poles is accepted as basic at present.*" He rightly feels that there is something arbitrary and unsatisfactory about the usual expositions in which the force between currents is taken as basic. This difficulty is a real one and is apparent even in the carefully considered teaching presentation suggested in the Report of the Coulomb's Law Committee of the American Association of Physics Teachers.[1]

Professor Hercus, in the *Bulletin* of December 1957, suggested that the major part of the answer to this challenge is to be found in the Ampère formula for the force between two current elements; he claims, with some justification, that the grounds given by Whittaker,[2] for rejecting Ampère's formula are not convincing. The formula due to Grassman (1845), which is that given in all modern conventional textbooks, was also rejected by Whittaker because it fails to satisfy Newton's third law; he gave a modification of the Ampère formula according to which the forces are no longer in the line joining the elements but do still satisfy the law.

It will, however, be shown in the following that the Grassman formula is correct and that the Ampère formula is untenable because it is incompatible with the restricted theory of relativity and with the accepted electrodynamical theory of electrons. In demonstrating this I have derived the Grassman formula in a way which has the incidental advantage of introducing convincingly the concept of the magnetic flux density; this, I think, is some help in meeting Professor Lipson's challenge.

Any discussion of a problem such as this is likely to be inconclusive unless the fundamental assumptions made are definitely stated. It will be here assumed that there is overwhelming evidence that the velocity of light is independent of the motion of its source[3, 4] and that the laws of mechanics of the restricted theory of relativity are valid. The latter assumption enables us to derive Grassman's formula from Coulomb's law; to do this we first calculate the force exerted on one moving charge by another, and then use this result to find the force exerted by one current-element on another.

THE INTERACTION OF TWO POINT-CHARGES

We suppose that, at the instant considered, one point-charge q is at the origin of co-ordinates of the reference system we are using, and a second point-charge q' is at the point $\mathbf{r} = r\,\hat{\mathbf{r}}$.

If the charge q is at rest, Coulomb's Law states that the force $\mathbf{F}'$ exerted by q on q' is given, in m.k.s. units, by :—

$$\mathbf{F}' = q'\,\mathbf{E} \quad ; \quad \mathbf{E} = \frac{q}{4\pi\kappa_o r^2}\,\hat{\mathbf{r}} \qquad (1)$$

thus introducing the electric field vector $\mathbf{E}$. It is assumed in all developments of field theory that equation (1) is applicable when q' is in motion, providing that q remains at rest.

If both the charges q and q' are moving, with uniform velocities $\mathbf{v}$ and $\mathbf{v}'$ respectively, the force $\mathbf{F}'$ exerted by q on q' can be calculated as follows :—

In terms of the measures of an inertial reference system in which q is at rest, i.e. a system moving with velocity $\mathbf{v}$ relative to our own, the force experienced by q' can be calculated by means of equation (1). We can then, by using the force-transformation formula of relativistic mechanics, find the value $\mathbf{F}'$ of this force as expressed in the measures of our own reference system.

We thus obtain the well-known approximate expression :—

$$\mathbf{F}' = \frac{qq'}{4\pi\kappa_o r^2}\left\{\left[1 - \tfrac{3}{2}\,(\mathbf{v}\cdot\hat{\mathbf{r}})^2/c^2 + \tfrac{1}{2}\,\mathbf{v}^2/c^2\right]\hat{\mathbf{r}} + \frac{1}{c^2}\mathbf{v}' \times (\mathbf{v}\times\hat{\mathbf{r}})\right\} \qquad (2)$$

or

$$\mathbf{F}' = q'(\mathbf{E} + \mathbf{v}'\times\mathbf{B}) \qquad (3)$$

where the part of $\mathbf{F}'$ that is independent of the velocity $\mathbf{v}'$ of q' is determined by the electric field $\mathbf{E}$ given by :—

$$\mathbf{E} = \frac{q}{4\pi\kappa_o r^2}\left[1 - \tfrac{3}{2}\,(\mathbf{v}\cdot\hat{\mathbf{r}})^2/c^2 + \tfrac{1}{2}\,\mathbf{v}^2/c^2\right]\hat{\mathbf{r}} \qquad (4)$$

which tends to the value given by equation (1) for small values of $\mathbf{v}$.

The part of $\mathbf{F}'$ that depends on the velocity $\mathbf{v}'$ of q' is determined by the auxiliary vector $\mathbf{B}$ given by

$$\mathbf{B} = \frac{\mu_o}{4\pi r^2} q\, \mathbf{v} \times \hat{\mathbf{r}} \quad ; \quad \mu_o = \frac{1}{\varkappa_o c^2} \qquad (5)$$

which may be referred to as the *magnetic flux density* due to the moving change q.

THE FORCE EXERTED BY A CURRENT ELEMENT ON A MOVING CHARGE

A current element $i\mathbf{ds}$, of a metallic conducting circuit carrying a current i, may be represented by n pairs of equal and opposite point charges q/n and $-q/n$ moving, with co-linear speeds u and v respectively, in the direction of the unit vector $\hat{\mathbf{t}}$ tangent to the current element. We can therefore write :—

$$i\mathbf{ds} = q(u-v)\hat{\mathbf{t}} \qquad (6)$$

In a metallic conductor at rest the speed u of the positive charges is zero but, since the element is characterized by the relative speed $u-v$, it is desirable to retain both u and v to avoid confusion in other cases.

The force $\mathbf{F}'$ exerted by such an element on a charge q', moving with velocity $\mathbf{v}'$ at the field point $\mathbf{r}$, can be evaluated by using equation (2) to find the contributions due to the positive and negative charges in $i\mathbf{ds}$. We thus obtain, on adding these contributions :—

$$\mathbf{F}' = \frac{qq'}{4\pi\varkappa_o r^2} \left(\frac{u^2 - v^2}{c^2} \left[\tfrac{1}{2} - \tfrac{3}{2}\,(\hat{\mathbf{t}}.\hat{\mathbf{r}})^2\right] \hat{\mathbf{r}} + \frac{u-v}{c^2}\, \mathbf{v}' \times (\hat{\mathbf{t}} \times \hat{\mathbf{r}}) \right) \qquad (7)$$

or, approximately :—

$$\mathbf{F}' = \frac{\mu_o}{4\pi r^2}\, q' \mathbf{v}' \times (i\mathbf{ds} \times \hat{\mathbf{r}}) \quad ; \quad \mu_o = \frac{1}{\varkappa_o c^2} \qquad (8)$$

This approximation is very close for any value of v' much greater than the electron drift velocity $(u-v)$ which rarely exceeds 0·1 cm/sec in metallic conductors. This equation may also be written :

$$\mathbf{F}' = q'\mathbf{v}' \times \mathbf{dB} \quad ; \quad \mathbf{dB} = \frac{\mu_o}{4\pi r^2}\, i\mathbf{ds} \times \hat{\mathbf{r}} \qquad (9)$$

and reference to equation (5) shows that we can define $\mathbf{dB}$ as the *magnetic flux density* due to the current element $i\mathbf{ds}$.

THE VALIDITY OF THE GRASSMAN FORMULA

We now consider a second current element $i'\mathbf{ds}' = q'(u'-v')\hat{\mathbf{t}}'$ at the field point $\mathbf{r}$. The total force exerted by the element $i\mathbf{ds}$ on this element may be found by using equation (7) or equation (8) to find the force exerted on each of the charges q' and $-q'$, and adding. Because the electrostatic forces between these charges are enormous, because the positive charges are those of the atoms which form the metallic structure, and because the total force thus calculated is normal to the element $i'\mathbf{ds}'$, we are justified in taking this total force as the *mechanical* force exerted on the element.

We thus obtain for the force $\mathbf{F}'$ exerted on the element $i'\mathbf{ds}'$ by the element $i\mathbf{ds}$:—

$$\mathbf{F}' = \frac{\mu_o}{4\pi r^2}\, qq'\, (u-v)\,(u'-v')\, \hat{\mathbf{t}}' \times (\hat{\mathbf{t}} \times \hat{\mathbf{r}}) \qquad (10)$$

or

$$\mathbf{F}' = \frac{\mu_o}{4\pi r^2}\, ii'\, \mathbf{ds}' \times (\mathbf{ds} \times \hat{\mathbf{r}}) \qquad (11)$$

which is Grassman's formula.

Thus Coulomb's law, taken together with the force transformation of relativistic mechanics, leads directly to the Grassman formula. The derivation is, in principle, rigorous although it is, strictly speaking, approximate. The expression of Grassman's formula in terms of magnetic flux density, and its application to closed circuits, follow the usual textbook lines and need not detain us here.

THE UNTENABILITY OF THE AMPÈRE FORMULA

The Ampère formula may be written, using the same notation as above, in the form :—

$$\mathbf{F}' = -\frac{\mu_o}{4\pi r^2}\, ii' \{2\,\mathbf{ds}.\mathbf{ds}' - 3\,\mathbf{ds}.\hat{\mathbf{r}}\,\mathbf{ds}'.\hat{\mathbf{r}}\}\,\hat{\mathbf{r}} \qquad (12)$$

where $\mathbf{F}'$ is the force exerted on $i'\mathbf{ds}'$ by $i\mathbf{ds}$ and is equal and opposite to the force $\mathbf{F}$ exerted by $i'\mathbf{ds}'$ on $i\mathbf{ds}$. Ampère showed that this led to the usual expression for the force exerted by a closed current on a current element, just as does the Grassman formula.

It can be shown easily[5, 6] that the Ampère formula (12) corresponds to, and can be derived directly from, the interparticle force formula of Ritz according to which the force $\mathbf{F}'$ exerted by q on q' is given by:—

$$\mathbf{F}' = \frac{qq'}{4\pi\varkappa_o r^2} \{1 + \mathbf{u}^2/c^2 - \tfrac{3}{2}\,(\mathbf{u}.\hat{\mathbf{r}})^2/c^2\}\,\hat{\mathbf{r}} \qquad (13)$$

where $\mathbf{u} = \mathbf{v}' - \mathbf{v}$ is the velocity of q' relative to q. The mutual force acts in the line joining the two charges and satisfied Newton's Third law; it depends only on the relative velocity $\mathbf{u}$ and no part of the force can be expressed in terms of the magnetic flux density as defined above.

The Ritz formula is derivable only on the hypothesis that all electromagnetic effects are emitted ballistically[5, 6, 7] and travel with a definite velocity c relative to their source. It is therefore incompatible with the principle that the velocity of light is independent of the motion of its source, and therefore with the restricted theory. It follows that *the Ritz and Ampère formulae are both incompatible with the restricted theory of relativity and are therefore untenable.*

It is to be noted that Moon and Spencer,[5] O'Rahilly[6] and Brown[7] have attempted to revive and promulgate the Ritz and Ampère formulae. All these authors reject the restricted theory of relativity and attempt, like Ritz, to achieve an electrodynamical theory compatible with simple Galilean relativity. Irrespective of their doubts about the validity of the restricted theory, it is difficult to see how they can fail to recognize the complete incompatibility of these formulae with the overwhelming evidence that the velocity of light is independent of the motion of its source; this evidence was, of course, not available to Ritz. Moon and Spencer[5] also deny that the Grassman formula is derivable from an inter-particle force formula; in view of the demonstration to the contrary given above, it can only be supposed that they did not consider any interparticle force formula other than that of Ritz.

CONCLUSION

It has thus been shown that the Ampère formula must be rejected, but that the Grassman formula can be derived from Coulomb's law by the force transformation of relativistic mechanics. This derivation also serves to introduce satisfactorily the concept of magnetic flux density.

The pedagogical advantages of this derivation are obvious. The concepts involved are quite definite and should be easily presented and grasped. It should not be overlooked that successful exposition on these lines would also give the student a valuable grasp of the physical relation between the electrodynamical phenomena observable in metallic circuits and the theory of metallic conduction. There are obvious difficulties in presenting the derivation at an elementary level; but the conventional presentations are in any case fraught with conceptual difficulties.

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1. *American Journal of Physics*, **18**, 69 (1950).
2. Whittaker, E. *History of the Theories of Ether and Electricity*, Vol. I.
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4. Builder, G. "The Constancy of the velocity of light," *Aust. Journ. Phys.*, Dec., 1958.
5. Moon, P., and Spencer, D. E. *Jour. Frank. Inst.*, **257**, 369 (1954).
6. O'Rahilly, A. *Electromagnetics*. Longmans (1938).
7. Brown, R. B. *Proc. Phys. Soc. B.* **68**, 672 (1955).

The Interpretation of the Special Relativity Theory

By Professor HERBERT DINGLE, D.Sc.

(Emeritus Professor of History and Philosophy of Science, University College, London)

RECENT work in nuclear physics has brought to light difficulties in the application of the special relativity theory to nuclear problems. Thus, in his recent book, *The Physicist's Conception of Nature* (London, Hutchinson, 1958, p. 48), W. Heisenberg writes : " Relativity theory assumes that in principle no effect can be propagated faster than the velocity of light. Now this trend in relativity theory leads to difficulties in connection with the uncertainty relations of quantum theory. According to relativity theory the only effects possible are in that part of space-time limited by the so-called light-cone, i.e., those points in space-time which can be reached by a light-wave emanating from the effective point. This region in space-time is thus—and this must be stressed—very strictly limited. On the other hand, we have found that in quantum theory a clear determination of position—in other words, a sharp delimitation of space—presupposes an infinite uncertainty of velocity and thus also of momentum and energy. This state of affairs has as its practical consequence the fact that in attempting to arrive at a mathematical formulation of the interactions of the elementary particles, we shall always encounter infinite values for energy and momentum, preventing a satisfactory mathematical statement. In recent years many investigations have been concerned with these difficulties, but so far no one has been able to arrive at a satisfactory solution."

Again, at the recent United Nations Conference at Geneva on the peaceful uses of atomic energy, H. Yukawa is reported (*The Times*, Sept. 11, 1958 —Yukawa's paper is not yet available) to have said that the difficulties are such that " it would probably be found necessary to have a breakdown of the special theory of relativity."

Quite apart from its application to nuclear problems, I have been led through recent discussions to re-examine the foundations of the special relativity theory, and a number of anomalies have come to light which appear to make some revision of present views inevitable. It is not necessary to say that the present theory has broken down, though ultimately it will become necessary to re-express the whole theory of relativity of motion in a simpler form. But for the present it is possible to retain the existing form with an amended interpretation of the quantities occurring in the mathematical equations, and this is all that is attempted in the present article. It will be shown that, with the revised interpretation, possible events are no longer confined within the light-cone (or, in other words, velocities greater than that of light are physically possible), and the difficulty described by Heisenberg is removed.

As an example of the anomalies associated with the present view, consider the following situation.

Two objects, A and B, separate at $t=t'=0$ with uniform velocity V. Each has a standard scale extending indefinitely in both directions along the line of their relative motion (Fig. 1).

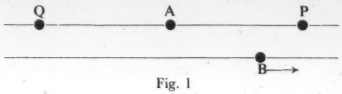

Fig. 1

At two points, P and Q, fixed on A's scale at equal distances, X, from A in opposite directions, are placed two screens, and by a suitable contrivance it is arranged that when a beam of light reaches a screen, a mark is made on B's scale giving its reading at that event : the scale with its marks can be examined afterwards at leisure.

At the instant of coincidence of A and B, beams of light set out in opposite directions from their meeting-point towards P and Q, reaching the screens simultaneously in A's rest-system at time X/c. Hence, by the Lorentz transformation, the (x', t') coordinates of the events of arrival of the light at P and Q will be $(X\beta, X\beta/c)$ and $(-X/\beta, X/c\beta)$, respectively, in B's rest-system, where $\beta = \sqrt{(1-V/c)}\,/\,(1+V/c)$. Hence, when the scales are examined afterwards, it will be found (if, as is always assumed, the x-co-ordinates are represented physically by the readings of the scales in question) that the first beam has travelled a distance $X\beta$ (which is less than X), and the second a distance X/β (which is greater than X) by B's scale, while each has travelled a distance X by A's scale.

Now the velocity of light is held to be c relatively to both A and B. Hence the difference of Q-readings requires that B's scale has contracted, and the difference of P-readings that it has expanded, relatively to A's. But the existing theory requires that it has uniformly contracted : whether the contraction is " real " or " conceptual " is immaterial here. Hence the existing theory needs amendment.

The error lies in the assumption that the velocity of the single beam of light is c relatively to both A and B. This is usually reconciled with their relative motion by converting them into " observers " and assuming that their measuring rods and clocks are modified so that each thinks himself at the centre of the light-sphere which expands from its source with velocity c. But this assumption fails here for two reasons. First, the measuring-rod modification takes contradictory forms. Secondly, whatever A and B may estimate the velocity of light to be, the only observer in this case is an outsider who examines the scales afterwards when they are both at rest beside him.

In such a case we have what amounts to observational proof that A and B cannot both remain at the centre of the light-sphere. Nova Persei (1901) was surrounded by a nebula which was observed some time after the outburst as a luminous ring expanding with the velocity of light as the light from the outburst reached successively more distant portions.* Suppose that, at the moment of outburst, another star, S, was immediately behind the nova and was moving across the line of sight with about half the velocity of light. From our experience of proper motions we know that when the light-ring had reached a radius r, this star would have appeared within it at a distance of about $r/2$ from the centre. Whatever might have happened to measuring-rods and clocks carried by it, we on Earth would have observed that it was not at the centre (Nova Persei) of the light-sphere with whose source it had been effectively coincident.

This is identical with the problem described above. A and B are Nova Persei and S, respectively ; their scales are linear elements of two inter-penetrating and normally dark nebulae, one of which we may suppose to surround each star and to be at rest with respect to it. The points P and Q are at the ends of a diameter of the luminous ring, and at each of them will be a particle of each nebula whose distance from its star will be the scale reading corresponding to the arrival of the light at P or Q. The conclusion is inescapable that A and B, as seen by an outside observer, are not both at the centre of the light-sphere, and consequently that, if the velocity of light is c relatively to A, it cannot be c relatively to B.

All experiments in physics are of this type. We do not travel with the particles we observe : we allow them to make records which we examine afterwards. Hence the assumption, inherent in the present special relativity theory, that those records are explicable in terms of supposed modifications of moving bodies, is false.

This is but one of several situations in which the present theory shows itself defective. They have been submitted to experts, who have not succeeded in resolving them. I have therefore been led to look for the defect, and have reached the conclusion that all anomalies disappear if one change is made, which can be expressed in various ways : the following, I think, is the most fundamental. It is at present assumed that two clocks, relatively at rest, which are synchronized by light-signals in the recognized way, record co-ordinate time (t) in the co-ordinate system in which they are both at rest. The defects are removed if, in fact, they record proper time (s). In that case a third clock, moved at uniform velocity from one to the other, will agree with the second if it agreed with the first. I have proved in fact, that this must be so if the relativity postulates hold, but there is no room for the proof here.†

This change, though slight, has profound implications : I hope to publish a full account elsewhere and can only summarize them here. With the cancellation of the difference between the readings of the " travelling " and " synchronized " clocks, the only *measure* of time between events is ds, and dt becomes, like dx, dy and dz, a mere co-ordinate, identifiable with a measure only in very special cases. Measured velocity is then $W \equiv dx/ds$ instead of $V \equiv dx/dt$, and it is easily deduced that $W = V/\alpha$, where $\alpha = \sqrt{(1 - V^2/c^2)}$. The Lorentz transformation remains valid, but loses much of its importance since V, in terms of which it is expressed, has become a mere mental artefact.

The measured velocity of light, c, must be regarded as a value of W, so that for light, $W = c$, $V = c/\sqrt{2}$. The postulate of constant light velocity becomes the postulate that the velocity, W, of a beam of light is always c *with respect to its source*

* See, for example, *Astronomy*, by Russell, Dugan and Stewart, Vol. II, p. 785, 1st edition.

†This has been maintained independently, on other grounds, by E. G. Cullwick (*Electro-magnetism and Relativity*—Longmans Green, 1957, p.75).

(which is not identical with that version of the "ballistic" theory in which light issues from its source with relative velocity c, but may thereafter have a different velocity relative to the source if the source "changes its motion"). A body having a velocity $V=c$ has a velocity $W=\infty$, and this accounts for the abnormal behaviour which bodies have been supposed to exhibit when moving with the speed of light, notwithstanding that their velocity is finite. There now seems no reason why a body should not move faster than light (indeed, if this view is correct, the velocity of light has already been surpassed), though it cannot have a value of $V>c$. The importance of universal time is restored (the current view recognizes proper-time, which is invariant, and co-ordinate-time, which is not, but identifies measurement with the latter. It would be misleading, therefore, to say that the proposed change restored universal time, for its existence, though not its significance, is already acknowledged). The length of a body becomes the distance between its ends when $ds=0$ and not when $dt=0$, and is therefore invariant. Mass also becomes invariant, so that the three phenomena which have been supposed to accompany high velocity—increase of mass, FitzGerald contraction and time dilatation—all disappear as characteristics of measured quantities and become mere co-ordinate curiosities. The formula for the Doppler effect also is changed. "Space-time" becomes a mere conceptual possibility, devoid of scientific or philosophical significance.

Notwithstanding the radical nature of these changes, all experiments, so far as I can see, that have yet been performed are equally explicable on the current and on the proposed view. Those, for instance, which are held to demonstrate the increase of mass (m) with velocity, actually show that momentum, if it obeys the conservation law, is measured by mV/α instead of mV. This has been interpreted as the product of a variable mass, m/α, and a velocity V, but it is equally explicable as the product of an invariant mass, m, and a velocity $W=V/\alpha$. Again, μ-mesons, travelling with a velocity estimated as V, have been held to show a mean lifetime exceeding that of resting μ-mesons by the factor α^{-1}. If their velocity is in fact V/α, their lifetime becomes invariant—they have had less time in which to decay than they have been credited with. And so on. In any experiment, in fact, in which a mass, a length or a time is associated with a high velocity, it is always possible to attach the factor α (which, if my view is correct, is necessary to convert the supposed velocity V into the true velocity W) to such mass, length or time unless a separate experiment is made to measure the latter quantity independently of the velocity. This is rarely practicable, and so far has not been done.

In view of the fundamental importance of the matter, it is highly desirable that the question should be submitted to a direct laboratory test if possible. The only crucial experiment I can think of that might at present be possible is the following.‡ Suppose a beam of radioactive particles, with a well-determined half-life when at rest, is accelerated to a high velocity in a cyclotron and made to travel a known distance X (not necessarily a to-and-fro journey) at a velocity estimated according to current views as V. Then, if n be the number which decay per unit of proper-time (i.e. the number which decay per unit of laboratory time when the particles are at rest in the laboratory), the number which will decay during the journey will be $\alpha nX/V$. This follows on either view, but whereas current ideas interpret the result as a retardation of rate of decay from n to αn per unit of laboratory time, the interpretation here proposed is that the rate of decay is unchanged but that the process has taken a laboratory time $\alpha X/V$, since the true velocity of the particles has been V/α. Hence, if the journey can be timed accurately *by a laboratory clock or its equivalent*, its duration on the current view would be measured as X/V and on my view as $\alpha X/V$. Any direct effect on the particles of the fields employed would, of course, have to be eliminated or allowed for. I hope that this test or some other can in fact be made.

I should add a note on the bearing of these changes on my previous publications concerning the clock paradox. The conclusion that the two clocks will agree on reunion is unaffected since that follows from the postulate of relativity which is antecedent to all these metrical considerations. The conclusion that this result is consistent with the orthodox interpretation of the Lorentz transformation also is unaffected, since the clocks are together at the beginning and end and the change here suggested affects only separated clocks. In my discussions of individual problems, however, it has sometimes been necessary to compare such clocks, and as I have done so in accordance with the orthodox view, the resulting comparisons I must now disown, as also I do the orthodox Doppler effect formula which I have used. It is impossible to enumerate corrections in detail, but this note should make that unnecessary.

‡The determination of the constant of aberration from a distant nebula might provide a test. This possibility is being examined.

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Snell's Law of Refraction

By F. BRYANT, B.A., M.Sc., A.Inst.P.

(*University of Melbourne*)

THE nature of the close fit between refraction angles calculated according to Kepler's formula ($i-r = ki \sec r$) and those obtained from Snell's law ($\sin i = n \sin r$) has been discussed recently in the *Bulletin*.[1] It is proposed in this brief note to indicate several points concerning the early history of Snell's sine law and also to mention some generally unappreciated mathematical aspects of the relationship.

Many physics text-books preserve the tradition that the sine law was first stated by Willebrord Snell (1591-1626) in 1621. However, it would appear that Snell could certainly have been aware of the relationship before this date (ref. 3 p. 26 ; ref. 8 p. 177 ; ref. 9) about the time when three English investigators, Hariot, Warner and Aylesbury seem to have verified the sine law with a simple and elegant experimental arrangement, using a glass prism.[4] Descartes (1596-1650) certainly deserves credit for the first formal publication of the sine form of the law in *La Dioptrique* in 1637, but many controversial points about priority of knowledge and plagiarism need detailed study in order to establish their actual chronology. (Ref. 2 ; ref. 5 p. 34 ; refs. 8, 9).

The mathematical equivalence of the Snell and Kepler laws for small refractions and when $n = \dfrac{1}{1-k}$ is well known. However the equivalence extends to larger angles as can be shown by a simple mathematical exercise. Using expansions in series and ignoring the very small terms of fifth and higher order, the standard sine relationship can be readily derived from the earlier and more cumbersome Kepler form.

From the assumed principle that "Nature always acts in the shortest ways," Fermat (1608-1665) discussed refraction by means of a procedure which has become a standard derivation of the sine law using velocities of propagation of light in two media and minimizing the time of travel along the optical path between a point in each medium. The repercussions and criticisms of this and later work in minimal principles became vital issues in the development of both optics and mechanics in the seventeenth and eighteenth centuries.[2,6] Many of the standard laws of the behaviour of mechanical, optical and electrical systems have been shown to be readily derived from the theory of stationary principles and in particular Fermat's treatment of refraction has come to be appreciated as an optical analogue of more general dynamical relationships.

Amongst the numerous points of physical and metaphysical criticism of Fermat's concept of minimization was its alleged teleological approach which involved consideration of the total path of a light ray in a way which suggested that the path itself ensured an extremal (minimum) time of passage for the light between the chosen points. This seventeenth century criticism can be obviated by the derivation of Snell's law using the calculus of variations. By applying the Weierstrass-Erdmann corner condition to the case of optical refraction, it has been shown that amongst other consequences, Snell's law follows not from treatment of the entire optical path but only from the behaviour at that point on the interface where refraction occurs.[7]

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The Fallacy in Physics and Mathematics

By A. D. MAUDE, Ph.D., A.Inst.P.

(*City of Liverpool College of Technology*)

HOWEVER much we of the teaching profession may regret it, what the student learns and the tasks into which he directs his energy are conditioned by the type of question which the examiner will ask him at the end of his course. If he knows that he will be asked to reproduce text-book proofs, hours must be spent becoming word perfect in these. To understand the subject matter may ease the burden on the memory, but a good memory will correspondingly ease the burden on the understanding. If the examiner will require descriptions of experimental techniques, these must be learnt in detail. A studious pupil might find satisfaction in understanding the reasons for these details, but it is doubtful whether it would gain him many marks.

"Discuss the relation between . . ." or "What is the importance of . . ." are much better, but such questions are notoriously difficult to mark and, although many examiners believe they can make a reliable judgment of a candidate's ability from such an answer, the best experimental evidence throws doubt on such a belief.*

There are, it is true, some good testing questions and problems which may be set, but the number is limited. Once a good question has been found it tends to re-appear in various disguises, until a standard answer appears in the textbooks.

However, there appears to be one almost inexhaustible source of "good" questions which has hardly been sampled as yet. I refer to fallacy questions. For example, the student might be asked to "show clearly where the fallacy in the following argument lies :—

> The difficulty of launching a space ship into inter-planetary space has been much exaggerated. The artificial satellites recently launched will end their career not, as is sometimes stated, by crashing to earth, but by being projected beyond the solar system. This is due to the resistance of the atmosphere which, whilst thin at great heights, theoretically extends throughout space. The air resistance will reduce he velocity of the satellite and this will change its orbit. To calculate this change of orbit we use the fact that the centrifugal force $\frac{mv^2}{r}$, must at all times equal the gravitational force F. It is known that the gravitational force is proportional to the reciprocal of the square of the distance from the centre of the earth, i.e. $F = \frac{k}{r^2}$. We may thus write
>
> $$\frac{mv^2}{r} = \frac{K}{r^2} \quad \therefore \quad r = \frac{K}{mv^2}$$
>
> From which it follows that, as the velocity decreases, the radius must increase. This process will continue until the satellite is ejected to a distance where the air resistance vanishes."

Three distinct advantages can be claimed from the widespread use of such questions, and these will be examined below.

The first, which has already been mentioned, is that the questions are "good." That is they are easy to find, easy to make, and test the understanding of the student rather than the memory. It is also quite impossible for the candidate to convey an impression of knowledge when none in fact exists. Whilst the examples quoted here are sufficiently advanced to provide the members of the Institute with a little mental exercise, they can as easily be set at an elementary level.

An error which occurs in the relativity section of a well known text-book may be adapted to exemplify this. Consider how impossible it would be to suggest that the fallacy in the following argument was understood, when in fact it was not. On the other hand, consider how a knowledgeable student could track it down by checking the truth at each stage.

> "Consider a collision between two smooth perfectly elastic spheres whose masses before impact are m_1 and m_2, and after impact are m_1' and m_2' respectively.
>
> Let the first sphere be travelling initially with a velocity v_1 along the x axis, whilst the second possesses a velocity whose component in the x direction is $-v_2$ and in the y direction is u. Suppose that the two spheres strike

* A discussion of evidence that essay type questions give only a rough indication of the ability of a candidate may be found in *Educational Psychology* by A. I. Gates, A. T. Fersild, R. T. McConnell and R. C. Challman, Macmillan Co., New York, 1942, or any other good book on educational psychology.

one another with their line of centres on the x axis, then as they are smooth, the first ball cannot be given a velocity in the y direction and will return along the x axis with a velocity v_1'. The second one, also, will not have its y component of velocity altered, but its x component of velocity will change to $+v_2'$.

As the law of the conservation of momentum applies in relativity physics, then by considering the y component of the momentum before and after impact we have :—

$$(m_1 \times 0) + (m_2 \times u) = (m_1' \times 0) + (m_2' \times u)$$
$$\therefore \quad m_2 = m_2'$$

Thus if mass is a function of velocity

$$v_2 = \pm v_2'$$

But, as this is not even roughly true in Newtonian mechanics when m_1 and m_2 have widely differing values, the assumption that mass is a function of velocity must be incorrect."

The second advantage claimed for the use of such questions is that it would relieve the overcrowded syllabuses. This would be particularly true in mathematics and for students destined for administrative posts.

In many cases, what the student requires is not sufficient skill to apply the mathematical tools, but sufficient understanding to follow the work of others.

To many engineering students a knowledge of trigonometric manipulation is required largely that they may understand calculations performed on the blackboard by a teacher. In such cases, a National Certificate syllabus could state that no question would be asked in which trigonometric identities would have to be proved, but fallacy questions might, instead, be included. At present students spend a considerable time practising the proving of identities in order that they may develop the ability of predicting the fruitful lines of approach. This ability they seldom, if ever, use later, so that such a statement would allow more time for other sections of the syllabus, without leaving the students with a serious gap in their knowledge.

Similarly, it may be essential that an executive understands the report from his statistician, but there is no need for him to be able to apply the analysis himself. Many research workers too would be glad of a wider knowledge of mathematics so that they would know what could be done, and would willingly sacrifice the depth of knowledge as this could always be acquired when the occasion demanded.

An example (based upon a section of a Ph.D. thesis!) will illustrate this.

" Consider a continuous function $f(x)$. If it is known from physical consideration that $e^x f(x)$ is unity when x is very large, and when $x = 0$, then if it is not a constant it must possess a maximum or minimum value.

Let $y = e^x f(x)$

$$\frac{dy}{dx} = e^x f^1(x) + e^x f(x)$$

for a maximum $\frac{dy}{dx} = 0$

$$\therefore f^1(x) = -f(x)$$

This is a differential equation whose solution is

$$f(x) = Ae^{-x}$$

The constant A may be determined from the fact that

$e^x Ae^{-x} = 1$ when $x = 0$ and when $x = \infty$

That is $A = 1$ and the required function is

$$f(x) = e^{-x} \quad "$$

With understanding, the error is obvious even to one who could never solve a differential equation or even differentiate any but the simplest expression. One drilled in the mechanics of calculus, on the other hand, might look in vain for a false step.

The most important benefit which would be derived from the widespread use of fallacy questions in examinations is that it would develop the ability to expose unintentional fallacies which occur from time to time in various learned journals and text-books. At present, this " fallacy spotting " ability is sadly lacking; a fact which leads to much wasted effort.

I do not pretend to know how pupils would be coached to produce in them the faculty of putting their finger on the error in an argument, but of this I am sure, as soon as it becomes important to possess such an ability a technique for implanting it will evolve. At one time psychologists assured us that it was impossible to raise the measured I.Q. of a child by more than two points by coaching. That was before the eleven plus examination had made such coaching " desirable." It is a brave man who would now put a definite limit to the extent to which coaching can affect the score in an intelligence test.

To illustrate the lack of the " fallacy spotting " ability, I present below a proof that the pressure of radiation is *towards* the source. As the argument is essentially simple, it would seem that the error must be obvious, but not one of the many intelligent physicists to whom it has been shown

has been able to tell me why the conclusion is not correct. Perhaps some reader can help ?

"Consider a train of monochromatic electromagnetic radiation of length l, cross sectional area A extending initially from $x = 0$ to $x = l$ and falling normally on a polished metallic plate initially at $x = 0$. If the plate is a perfect conductor no electric field can exist in it, and the electric field of the incident radiation at the metallic surface must be at all times equal and opposite to an electric field which constitutes part of a reflected train of waves It follows that there will be a reflected train of waves of the same amplitude as the incident train. This conclusion holds if the reflector is moving with a velocity v in the positive direction of x, although the frequency of the reflected radiation will then differ from that of the incident radiation.

If the velocity of electromagnetic waves is c, then after a time $l/(c+v)$ both the reflector and the trailing edge of the radiation will reach the plane $x = vl/(c+v)$, so that the whole of the train of waves will have been reflected. The leading edge of the reflected radiation will have reached the plane $x = cl/(c+v)$, so that the reflected train will occupy a volume $A\,[cl/(c+v) - vl/(c+v)] = A\,l\,(c-v)/(c+v)$.

The energy density E in the reflected ray will be the same as that of the incident ray as their amplitudes are the same, so that there will have been a decrease in the total energy in the radiation due to reflection, from EAl to $EAl(c-v)/(c+v)$. As the system is conservative this change of energy of $2EAlv/(c+v)$ must have been passed to the agency which moved the reflector. Thus there is a force F on the reflector of such a magnitude that in moving from $x = 0$ to $x = vl/(c+v)$ it receives energy of $2EAlv/(c+v)$. That is, the force is $2EA$ *towards the radiation.*"

However, all the text-books state that radiation pressure is in the opposite direction, and they could not all be wrong—I suppose ?

Reviews of Books

INVESTMENT IN INNOVATION

By C. F. Carter and B. R. Williams

London : Oxford University Press. Pp. 167. Price 15s.

Carter and Williams have returned to the evidence of their case-studies of 250 firms, which was reported in *Industry and Technical Progress*, to seek knowledge of how investment decisions are made in industry. They have restricted the investigation to finding the reasons why industry invests in innovation, as distinct from plant replacement, and this limitation makes their study of particular interest to scientists.

Scientists, and particularly those in industry, must often turn over in their minds how opportunities arise for investment and how business men decide to invest. They will find in this book a most readable account of these investment processes, largely coinciding with their own impressions, but highlighted and put on a more quantitative basis with examples from the case-studies. Yet, the book goes further than this, for its conclusions are somewhat different from those often accepted : finance, for example, does not turn out to be a greatly limiting factor for investment in innovation ; lack of suitable management is much more important.

Indeed, the problem of management recurs throughout the study. Managers to maintain a running organization are in reasonable supply, but those who can engender the new methods required for innovation, are very hard to find. The problem is, once again, that of changing from those who know "how" to those who know "why," a change, in short, from the technician to the technologist manager. Does this forecast that a scientific education may, after all, be an essential preparation for higher management ? Or does it merely indicate that able minds are limited in number, and that this rather than, finance determines our rate of progress ? We can, of course, organize industry to lessen the effect of this limitation, and Carter and Williams' book does offer guidance on this important finding. They stress the need for education in management and for a greater entry into industry of those who are scientifically literate. They find, too, that the

decision to commit resources to research and development is the prime mover in the creation of investment opportunities, whilst better direction of research and better integration of research with industrial organization would eliminate much waste effort.

Their survey was made during a time of excess demand, and their conclusion that excess demand is an important cause of investment in innovation follows as a matter of course. Price competition, they hint, may also lead to investment in innovation but it is a conclusion that they were unable to test at all accurately. Trading conditions to-day could be used to throw much more light on the value of price competition as a stimulus to innovation, and every effort should be made to continue the survey under present economic conditions.

A. B. D. CASSIE.

THE FUNDAMENTAL CONSTANTS OF PHYSICS

By E. R. Cohen, K. M. Crowe and J. W. M. Dumond

London : Interscience Publishers Ltd. Pp. xii + 287. Price 58s.

In many ways this book is unusually refreshing. It is perhaps unlikely that the detailed information given in all the chapters will be of interest to any one person, nevertheless most physicists would benefit from reading some parts carefully. There are eight chapters of widely varying length. The first is extremely short and serves as an introduction, while the second is a brief outline of the basic system of physical units commonly used, and includes details of the standardization procedures. The third chapter is a rather short account of measurements made on the classical constants, such as the acceleration due to gravity, the gas constant, the Faraday, etc.

The fourth, and one of the longer chapters contains a review of methods for the measurement of atomic and meson constants. The first section, on atomic masses, is very brief and does not include mass spectrometry. The rest of the chapter is devoted to masses and other properties, particularly lifetimes, of the π- and μ-mesons, the K-meson and the hyperons. Very accurate data are nowa vailable for the π- and μ-mesons but the situation is still in considerable flux for the strange particles. This chapter is probably the most concise account of the data available in the early part of 1957 and includes an excellent bibliography.

Chapter 5 is a long account of the history of the atomic constants, particularly e, m and h and the various combinations of those quantities which can be accurately measured. A considerable wealth of detail is included in this chapter but it avoids being boring. The chapter concludes with the Birge-Bond diagram and several isometric consistency charts which are not very well produced. Chapter 6 contains an account of some selected postwar high-precision measurements, mostly in the field of microwave techniques.

Chapter 7 contains a theoretical treatment of least-squares methods and the last chapter contains a detailed least-squares evaluation of the best values for the principal atomic and nuclear constants, based on data available in 1955.

The book is mainly well-produced and all the chapters have extensive bibliographies.

C. C. BUTLER.

THE UPPER ATMOSPHERE

By H. S. W. Massey and R. L. F. Boyd

London : Hutchinson and Co. Ltd. Pp. xii + 333. Price 63s.

The authors give an account of the present state of knowledge of the upper atmosphere—the region extending from an altitude of about ten miles to some hundreds of miles into space. Although the atmospheric pressure in most of this region is so low as to constitute a good vacuum, there are still 10^{10} molecules per c.c. at 170 miles, and the phenomena occurring in the upper atmosphere have a profound influence on the propagation of radio waves, the absorption of ultra-violet rays from the sun, and the behaviour of artificial satellites.

The book opens with a chapter on elementary physics, which gives an account of those aspects of electricity, magnetism, wave motion and atomic physics which are required for an understanding of the main text. In the reviewer's opinion, however, the authors have overestimated the capabilities of a reader with very little scientific knowledge. It is very doubtful if any reader who requires an explanation of the term "wavelength," or a full description (with diagrams) of a gold-leaf electroscope, would be able to understand, for example, the effect of the earth's magnetic field on the propagation of radio waves in the ionized layers. Accordingly some of the more elementary information could have been omitted. Incidentally, the formula for refractive index on p. 17 is inverted.

Chapter 2 summarizes the properties of the upper atmosphere—composition, temperature and pressure, ionization—and also discusses aurorae,

meteors and cosmic rays. Chapters 3 to 5 describe the methods and techniques used to study the upper atmosphere—balloons and rockets, sound waves and radio waves. Chapters 6 to 11 deal with important external influences such as solar radiation, cosmic rays and meteors and their effects. Chapter 12 is a topical and up to date account of the artificial satellite projects, and in the final chapter future possibilities are discussed.

The text is excellently illustrated with numerous line diagrams, 21 black-and-white plates, and six colour plates, including three remarkable colour photographs of aurorae.

From the wealth of exciting discoveries which the authors present, it is difficult to select the more noteworthy, but one must pay tribute to the ingenuity of the experimental methods employed to build up the extremely complicated picture of the upper atmosphere as we now see it. For example, an ionized cloud, detectable by an ionospheric recorder on the ground, was produced artificially by releasing nitric oxide from a rocket at a height of 58 miles, and as the authors point out, the high atmosphere may well be used as a laboratory for photo-chemical studies free from complications due to boundary walls.

Another *tour de force* is the detection of the impact on a rocket nose cone of particles weighing 10^{-13} oz. The occurrence of minute quantities of sodium in a layer about 50 miles above the ground is also a great interest and has not yet been explained.

The book can be thoroughly recommended to anyone with a knowledge of physics of about "A" level standard. In fact any physicist who does not find the story of absorbing interest should (with acknowledgements to Rutherford) give up physics and take up stamp collecting.

J. S. Forrest.

FOUNDATIONS OF INFORMATION THEORY

By A. Feinstein

New York and London : McGraw Hill Publishing Co. Ltd. Pp. x+137. Price 50s. 6d.

Although the author of this book develops his theory from a minimum set of axioms, the treatment is at a level of abstraction which will not appeal to most practising physicists in this country. For example, acquaintance with measure theory and Lebesgue Integration are almost essential if the book is to be read without additional help. With this proviso, however, the author has produced an excellent and rigorous derivation of the fundamental theorems of information theory.

The first two chapters develop the notion of a measure for information from three extremely general conditions which it must satisfy and lead, after a discussion of some basic problems, to the so-called " noiseless coding theorem " of Shannon. Chapters three to five consider aspects of information transmission in channels without memory, and chapter six extends the analysis to the discrete channel with memory. The difficulty of rigorous treatment in this field is well illustrated by the remark on page 96, " Finally, the case of semi-continuous channels with memory . . . is not too well understood at present."

The concluding chapter, seven, contains some remarks on checking by means of parity codes which are of considerable interest to the mathematician.

There is a good set of references and an index.

A. D. Booth.

NOTES ON ANALOG-DIGITAL CONVERSION TECHNIQUES

Edited by A. K. Susskind

London : Chapman and Hall Ltd. Pp. x+410. Price 80s.

This book has the ingredients of a useful work. It consists of eight independent chapters, most of which contain useful material. The first introduces the subject with a discussion of data processing and of the SAGE air defence system ; the second is concerned with the theory of sampling and is very well written ; the third, also clearly written, deals with codes, especially the cyclic-progressive and checking kinds ; the fourth wanders over the whole field of digital computing from gate circuits to magnetic shift registers the material is selected at random, and, although it may have proved useful had it been given some shape and then been expanded to include relevant details, it cannot in its present state be of interest to anyone relatively unacquainted with computer mechanics.

Chapters 5, 6 and 7 deal respectively with the electronic techniques of digitizing, electro-mechanical coders and the approach to a complete system design, and the book ends with an excellent and original study of optical coding systems.

It is a pity that the book is so badly produced since much of the material is good and clearly written. As it is, however, it is obviously composed of lecture notes taken wholesale and without adaptation to suit the printed word. Added to this, the pages are numbered in chapters not as a whole, and there is no index. The price is

inordinately high in comparison with the scope covered and the quality of production, and these three factors will probably deter readers who would otherwise find it of use.

A. D. Booth.

AN INTRODUCTION TO THE THEORY AND PRACTICE OF SEMI-CONDUCTORS

By A. A. Shepherd

London : Constable and Co. Ltd. Pp. 206. Price 18s. 6d.

This book is written for students with a general knowledge of physics but no previous knowledge of semi-conductors.

The subject matter of the book falls into three categories. First the electrical properties of semi-conducting materials are discussed. Next an account is given of the purification and preparation in single crystal form of the two most commonly used materials, germanium and silicon. Thirdly the use of these materials in rectifying, amplifying and photosensitive devices is treated at some length. A final chapter lists briefly the properties and possible uses of some semi-conducting compounds.

The book is largely non-mathematical and is written in an easily readable style. Equations necessary to supplement the text are in general quoted, with reference to a research paper, rather than derived. In a work of this length, this is unavoidable. However, the student may sometimes wish for more detailed treatment without having to refer to another source. A particular example is that of the theory of the *p-n* junction. This is dealt with rather summarily considering its importance in almost all semi-conductor devices, indeed the metal-semi-conductor contact is treated more fully. By contrast, a considerable amount of practical detail concerning the manufacture and performance of devices is given. Most types of transistor at present under development are described, giving the reader a picture of their scope and rapid development in the last ten years. No mention is made, however, of the use of semi-conductors for thermo-electric refrigeration or generation.

The diagrams could in some cases be improved; two of them, Figures 2 and 44, are misleading in the physics they are meant to illustrate. The use of incorrect notation in Figure 44 leads to errors in the text and equations on the following two pages which will confuse the reader. Some confusion will also arise due to the wording of the text at the foot of page 25.

The criticisms apart, this book will be found very useful by students who require a general introduction to the subject of semi-conductors, particularly if their interests lie principally on the practical rather than the theoretical side.

B. Dale.

SPECIAL RELATIVITY FOR PHYSICISTS

By G. Stephenson and C. W. Kilmister

London : Longmans Green and Co. Pp. 108. Price 18s.

This book is written for the non-specialist in relativity theory, in particular for experimental physicists and students in degree courses in physics or mathematics. In view of this the mathematical demands on the reader are limited to a good working knowledge of three-dimensional vector analysis. No use is made of tensor calculus, and no mention is made of Minkowski's interpretation of the theory in terms of four-dimensional geometry.

The first two chapters deal with the Lorentz transformation and its immediate consequences, while the remaining two chapters cover optical and dynamical applications, and applications to modern physics, respectively. As a summary of results dependent on the special theory for the specialist this book may be admirable. But for the type of student mentioned above, it seems to the present writer that far too much has been compressed into just one hundred pages. A little more discrimination might have been exercised in the choice of applications. For example, it is difficult to see what useful purpose is served by deriving the Lorentz invariant form of the equations of hydrodynamics when no use is to be made of them.

One has the impression also that brevity is often achieved by omitting intermediate steps or explanation to an extent which will make the book difficult reading for the undergraduate and non-specialist.

The variety of notations which have developed in vector analysis is regrettable, and one would welcome and support any move towards uniformity such as has been shown recently by the use of " rotation " instead of " curl " in American texts and of the cross symbol for the vector product in German texts. It seems a pity that this book and others in this country should retain the inverted v symbol for the vector product. The printing of this symbol, and also the nabla symbol, below the normal line of the type gives an unpleasant appearance to some of the equations.

Two pages at the end of Chapter 2 are devoted to the " clock paradox," in which what one might describe as the orthodox mathematical argument is given. The opposing view, however, is not stated so that although references are given, nothing of significance is contributed to this controversy.

A. W. Gillies.

Branch and Group News

Midland Branch and Electronics Group : Symposium at Malvern

A joint symposium of the Midland Branch and the Electronics Group was held in the Winter Gardens, Great Malvern, early this summer. The subject was " Some Applications of Solid State Physics in Computers and Automation." The Midland Branch Chairman, Dr. R. E. Bastick, took the chair for the morning session ; Dr. M. E. Haine, the Electronics Group Chairman, for the afternoon.

Dr. R. A. Smith, head of the Physics Department, Royal Radar Establishment, Malvern, introduced the subject. He was followed by two other speakers from R.R.E. Mr. G. H. Perry gave a very lucid account of the use of transistors and magnetic cores for digital computors. Dr. E. H. Putley, described the application of automatic measuring techniques to research work. The automation was effected by fitting digitizers to Honeywell-Brown recorders and the output, punched on teleprinter tape, fed into a digital computer. The results could be presented either as a printed table or graphically by means of a curve plotter. The use of this technique has enabled the number of experiments completed in a given time to be increased by a considerable factor over what was possible before. It has made certain experiments possible which would have been too arduous to have undertaken with manually operated equipment. A lively discussion ensued in which the speakers were asked about future trends in their respective fields and the reliability of the devices.

In the afternoon Dr. D. Shaw, of British Thomson-Houston Co. Ltd., Rugby, talked about cadmium sulphide photocells. He described two types, the first of which had a small sensitive area (of about 1 mm^2) which was in an advanced state of development. The second type was a large area experimental cell capable of two to three watts dissipation. He gave some indication of the potential applications of these types of cells.

Under the title of "Semi-Conductor Multipliers" Mr. C. Hilsum of Services Electronics Research Laboratory, Baldock, Herts, discussed the employment of the Hall and magneto-resistance effects in analogue multipliers. High mobility semi-conductors should be employed for a multiplier feeding into a matched load. Silicon and germanium are satisfactory materials when amplification after the multiplier is permissible. Details were given of three multipliers based on the Hall effect and one based on the magneto-resistance effect, together with predicted performance for the latter.

After a discussion on these two papers thirty members were taken by bus to the Royal Radar

Establishment to see selected parts of the work in progress pertinent to the day's discussion.

(*Copies of the photograph may be obtained direct from Mr. R. A. Gammons at the Winter Gardens, Malvern. Price 3s. each*).

R. J. WAKELIN.

North-Eastern Branch : Visit to Calder Hall

On Saturday, September 20, the North-Eastern Branch held a whole-day Summer Meeting in West Cumberland. Forty-five members and guests took part in the meeting which was opened at 9.30 a.m. at Windscale by the Branch Chairman, Dr. O. P. T. Kantorowicz. After a short welcome to members he introduced the first speaker, Mr. J. Moore (*Associate*), who talked about the experiments which had been carried out on the Calder Hall reactors. Details were given of measurements made during commissioning and also of more recent experiments on the operation of graphite-moderated piles. After an interval for coffee there followed two papers on Radiation Damage. Mr. H. Bridge (*Associate*) discussed the forms of damage which can occur and gave particular consideration to the effects in carbon. He described how stored energy may be released. This talk was followed by one by Dr. V. Eldred who dealt with radiation damage in metals, especially in the fuel elements. Details were given of the causes of can fracture and of the measures which are taken to avoid this.

An excellent lunch was served at the Windscale canteen and members afterwards heard a talk on the Calder Hall installations by Mr. C. Banner. This was both instructive and entertaining and served as a good introduction to the tour of Calder Hall which followed. The path of the fuel was followed from its arrival in a box from the canning plant to its departure in a " coffin " for the plutonium separation installations. The operations of charging and discharging were described and details were also given of the instrumentation of the pile. The control room was visited and the various safety devices explained. After a short visit to the turbine house members reclaimed their cameras at the main gate and left Calder Hall at 5.30 p.m.

Some members returned to the North-East immediately after the tour of Calder Hall, but for local members and those who were staying overnight in Seascale a dinner was held at the Scawfell Hotel, Seascale. This was an enjoyable informal occasion attended by 21 members and guests. In a short speech the Branch Chairman took the opportunity of expressing thanks to those who had contributed to the success of the meeting, to the United Kingdom Atomic Energy Authority for permission to hold the meeting and for providing transport between Seascale, Windscale and Calder Hall, to the lecturers and not least to Dr. G. C. Curtis (*Associate*) who had made all the local arrangements.

It is hoped to arrange periodical lecture meetings in Seascale for the benefit of members in West Cumberland.

W. D. CORNER.

London and Home Counties Branch : Visit to Ewell County Technical College

On the afternoon of October 1, 1958, members of the London and Home Counties Branch visited Ewell County Technical College. They were shown round the science laboratories by Mr. R. L. D. Ellis, Head of the Science Department, and his staff. The College is a modern building, and the light well-equipped laboratories looking out on the open Surrey landscape were much admired. The College caters for the local industries and provides courses in chemistry, biology and physics. There is also a comprehensive building department with courses up to H.N.C. level.

After tea the party attended a meeting held jointly with the College Faraday Society. Mr T. A. Buchanan, Principal of the College, welcomed the members of the Branch, and said that he was pleased to have the opportunity of fostering the very cordial relations which had always been maintained between the College and The Institute of Physics. Professor A. M. Taylor, Chairman of the Branch, then introduced the lecturer, Mr. D. H. Lucas (*Fellow*) of Central Electricity Research Laboratories, who spoke on " Theory, Measurement and Responsibility in Atmospheric Pollution." He showed that, although the detailed theory of atmospheric pollution was very complicated and unsatisfactory in many respects, it was possible to deduce the broad principles from simple physical considerations. The pollution caused by a chimney is inversely proportional to the square of its height, and a large number of low level domestic chimneys is a serious cause of pollution. Apparatus for the measurement of pollution was described and some recent developments exhibited. In conclusion, Mr. Lucas showed a film illustrating the use of balloons for tracking the paths of particles emitted from chimney stacks.

A vote of thanks to the lecturer was proposed by Mr. A. C. Hoare, the Vice-Chairman of the Governing Body and Chairman of the Science Advisory Committee, and finally, Professor A. M. Taylor thanked the Principal for making it possible for the Branch to enjoy such a pleasant and instructive visit.

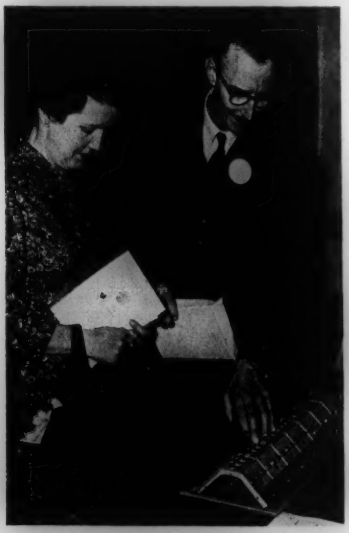
J. S. FORREST.

London and Home Counties Branch : "At Home"

This social gathering of London Branch members and their wives and friends, held on October 31, followed the general pattern of the previous "At Homes" held in 1951, 1953 and 1955. The response for tickets showed that this type of social function is very popular and it is much regretted that the space available in the Institute's House made it necessary to limit the attendance to 150 and to disappoint some applicants.

The steady stream of arrivals at 47 Belgrave Square from 7.30 p.m. onwards found the House quite transformed from its normal workaday aspect. The hall and staircase were tastefully decorated by floral displays, whilst the Members' Room and Lecture Room were transformed into an acoustic theatre and cinema respectively. Other rooms around the house contained obscure and interesting exhibits showing the impact of physics on everyday life.

Dr. F. W. Wood, a member of the Committee of the Institute's Australian Branch.



Dr. and Mrs. J. S. Preston.

It was to the Board Room, however, that the visitors' steps were first directed. Here the Branch Chairman, Professor A. M. Taylor, with his charming daughter, conducted a pleasantly informal reception. (Mrs. Taylor was just recovering from a serious illness and was not able to be present—we wish her a speedy convalescence.) A steady hum of conversation indicated that everyone was feeling "At Home", helped no doubt by the glasses of sherry to be seen on all sides. It is pleasing to record that a quick glance round the assembled company showed a good cross-section of the Branch membership, from the young students to the Fellows of many years' standing.

Shortly after this, small groups were to be observed setting off to explore the rooms containing the exhibits and demonstrations. Foremost amongst these must be ranked the demonstration of stereophonic sound provided by the B.B.C. Research Laboratories. The impression of realism created by these recordings was very great indeed

Professor A. M. Taylor and Miss Taylor with Lt.-Col. and Mrs. H. S. Young.

Professor and Miss Taylor with Dr. and Mrs. J. S. Forrest and Master J. R. Forrest.

Dr. and Mrs. D. H. Follett.

and this show played to full houses throughout the evening. Elsewhere, a small brightly fluorescent ball spinning and hovering in the air with no visible means of support to the accompaniment of " bleep-bleep " noises, was taxing some of the best brains of the London Branch. The presence of two important looking magnets was generally considered to be the cause of the levitation. The demonstrator, hovering in the background, was observed to be deriving considerable amusement from the improbable explanations being put over to unsuspecting wives.

In other parts of the House were to be seen some interesting display panels of the use and properties of the more important plastic materials, an elegant demonstration of the generation and properties of static electricity kindly supplied by the Science Museum, and a reaction timer on which visitors were able to judge their speed of response to a visual stimulus. These exhibits and many others provided interest throughout the evening. The film shows, too, were popular, covering a range of subjects from insect natural history to the principles of high speed flight. Meanwhile, an excellent buffet supper was being served in the Board Room.

So ended a successful and enjoyable evening. Our thanks are due to the organizations supplying exhibits, to their demonstrators, and above all to the Institute's permanent staff who worked to such good effect on behalf of the London Branch.

D. T. R. DIGHTON.

Liverpool and North Wales Branch : " The Physicist in Industry "

Arising from a suggestion by Mr. Hurley, the Branch Chairman, a meeting was held on Thursday, November 13, to discuss " The Physicist in Industry." It was felt that more knowledge of how and why physicists are employed in industry would be particularly valuable to school teachers who had to advise their pupils on the choice of a career.

The meeting was held in the new School of Medicine of Liverpool University, and was attended by about 140 people. About three-quarters of these were school teachers and their guests. From 4 to 6 p.m. the time was devoted to hearing the views of four distinguished industrial scientists from different industries. A fairly full account of their interesting contributions will be published in a later issue of the *Bulletin.*

Mr. G. S. Bosworth (Chief of Technical Personnel Administration in The English Electric Co. Ltd.) gave a clear and humorous account of the organization of an industry. He indicated the parts in which physicists were employed and the channels through which they entered them.

Dr. H. Kronberger (*Fellow*) (Director of Research and Development Industrial Group, United Kingdom Atomic Energy Authority) stressed the advantages of physicists for a wide range of industrial posts. They had a universal outlook and were brighter than those who entered industry through other channels.

Mr. J. Bunton (*Associate*) (Mullard Ltd.) gave an account of the ways in which physicists are employed in the electronics industry. With the exception of factories manufacturing equipment all departments employed a high percentage of physicists. They were appreciated for the freshness of their approach, their adaptability, as well as for their specific knowledge.

Dr. B. W. Bradford (Director of Research and Development, Billingham Division, Imperial Chemical Industries Ltd.) described the contribution of physicists to the chemical industry which he said, takes 10 per cent of all graduate physicists. Their prospects in this industry were just as good as those of the chemists.

After an interval for refreshments the four speakers, with the Branch Chairman, sat on the platform as a " Brains Trust." In reply to a question it was stated that there was no prejudice

against employing girls in many scientific posts in industry, although traditions in the manufacturing side were against it. There was considerable disagreement about the best method of entry for the not too bright pupil, e.g. ordinary degree or sandwich course. It was stressed that academic qualifications were not a good guide to success in industry. This view appeared to be taken to rather extreme lengths by some of the speakers, and inevitably drew a protest from the audience. In this connection there was strong disagreement about the value of a Ph.D. One member of the audience from industry was concerned about lack of knowledge of industrial organization and methods, and felt that universities and even schools should provide courses on this subject. The general feeling was that while such courses are valuable the task of the schools and universities is to teach fundamental principles and to develop a broad outlook.

A. ASHMORE.

Forthcoming Institute Meetings

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Dec. 15	**Manchester** The University	Dr. E. B. Mendoza (*University of Manchester*)	**Electronic applications of superconductors**	6.45 p.m.	Manchester and District
Dec. 16	**London** The Institute's House	Prof. K. W. H. Stevens (*University of Nottingham*)	**Ferromagnetic microwave amplifiers**	5.30 p.m.	Electronics
1959					
Jan. 8	**Liverpool** The University	Prof. J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.00 p.m.	Liverpool and North Wales
Jan. 14	**London** Royal Institution	The President of the Institute, Sir George Thomson, Hon.F.Inst.P., F.R.S. (*University of Cambridge*)	**Controlled Thermonuclear reactions**	5.30 p.m.	London and Home Counties

Admission by ticket only.

The Institute's Journals

PRINCIPAL CONTENTS OF THE DECEMBER, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 12

ORIGINAL CONTRIBUTIONS

A thermometer for high-speed aircraft. By D. D. Clark.

The principles of aircraft thermometer design are reviewed, from which it is deduced that the conical head design possesses distinct advantages over other kinds of thermometer head in high-speed flight. The construction of the thermometer is described and the results of wind-tunnel tests are quoted and discussed. The lag and radiation errors are calculated and the extension of the use of the thermometer to supersonic flight is discussed. An outstanding feature of this thermometer is the remarkable constancy of the recovery factor over a range of Mach numbers from 0·2 to 0·9 and its rapid response to temperature changes, the lag coefficient being of the order of 2 s.

The measurement of the dielectric properties of liquids in an H_{01} resonator. By J. S. Dryden, F.Inst.P.

A simple container which has proved suitable for the measurement of the dielectric properties of liquids in an H_{01} resonator is described, together with a method of correcting for the meniscus.

A self-adjusting unit for the control of an animal calorimeter. By A. E. Hawkins, A.Inst.P.

A unit is described which automatically adjusts the value of a continuous current passing through a coil placed in a chamber so that the rate of heat dissipation duplicates that released by a small animal in a similar chamber.

A thermocouple method for measuring relative humidity in the range 95-100%. By J. L. Monteith, A.Inst.P. and P. C. Owen.

At high relative humidities a current of 30mA through a 38 s.w.g. chromel-*p*/constantan thermocouple produces sufficient Peltier cooling to form a film of water on the junction which may then be used as the wet-bulb of a psychrometer. The wet-bulb depression can be read to 0·001°C and in the range 97-100% changes of 0·01% relative humidity can be detected. After calibration over sodium chloride solutions the psychrometer has been used to determine the water content/free energy curves of two soils, and good agreement has been obtained with previous determinations by other methods.

A simple orbit contractor for betatron-started synchrotrons. By J. Moffat.

The contractor uses a small thyratron to control the current in a coil around the betatron flux of the machine, the current being supplied by the changing betatron flux. The X-ray yield is increased by a factor varying from three to twenty.

A precision, direct-reading, colour temperature meter. By P. Hariharan, A.Inst.P., and M. S. Bhalla.

The measuring element in the instrument described is a photomultiplier tube operated in a logarithmic difference circuit which views, alternately through red and blue filters, a diffuser illuminated by the lamp which is being calibrated. The output from the circuit is linearly proportional to the reciprocal of the colour temperature of the lamp and is independent of its brightness. Readings can be made with an accuracy of approximately ±5° K over the colour temperature range from 2200 to 3200° K.

A temperature-chlorinity-depth recorder for use at sea. By B. V. Hamon and N. L. Brown.

An instrument for recording temperature, chlorinity and depth in the upper 1000 metres of the sea is described. The temperature range is 0—30° C, with an accuracy of ±0·15° C. The chlorinity range spans about seven parts per thousand of chlorinity, the accuracy being ±0·03 parts per thousand. The accuracy in depth is ±10 m. The three quantities are recorded sequentially by a single-pen strip-chart recorder, each quantity being recorded for five seconds at a time. The underwater unit is suspended by means of an armoured steel cable, which has a single electrically-insulated core. This core carries power down to the underwater unit, and brings up the signals from the measuring elements. A simple frequency-modulation method of telemetering is used.

A technique for the measurement of diffusion coefficients in molten salts. By C. A. Angell and J. O'M. Bockris.

A diffusion method is described in which two columns of molten salt to be interdiffused, initially separated by a gas bubble at reduced pressure, are joined by breaking a capillary and allowing external pressure to eliminate the bubble. After a period of diffusion, the salt distribution is preserved by causing the glass diffusion tube to break at the point of initial junction while the tube is still in position in the high temperature zone of the furnace. The method has been tested with a 1·1 $CdCl_2$-KCl mixture. The self-diffusion coefficient of cadmium is found to be 1·40 cm^2 sec^{-1} at 470° C, with a probable error of 2·5%. The method is applicable up to temperatures of the order of 1000°C.

An apparatus for visual and acoustical display of electrocardiograms. By A. Strojnik.

A simple electrocardioscope with a cathode-ray tube and an electrocardiophone are described for use in lectures and during surgical operations. The electrocardiophone can be attached to the cardioscope amplifier and converts the amplified bioelectric potentials into signals of constant audio frequency and of variable intensity.

A very sensitive relay, able to withstand heavy overloading. By F. H. Plankeel.

A galvanometer relay is described which consists of a mirror galvanometer with limited deflexion, an optical system, a photoconductive cell, a Wheatstone bridge and a polarized relay. The input is a small d.c. current supplied to the galvanometer coil. The output is the energy available at the switch contacts of the polarized relay. The power amplification, i.e. the ratio between minimum input energy necessary to actuate the relay and maximum output energy available at the contacts of the polarized relay, is, in the simple prototype, $1 : 10^{13}$; the figure for a commercially produced version could be much higher. Large input overloading is allowable, e.g. a current 100,000 times greater than the minimum failed to damage the instrument. The instrument described is already quite small ($4 \times 4 \times 6$ in.), but improvements in its design could reduce the size still further.

Image intensifier for the electron microscope. By M. E. Haine, F.Inst.P., A. E. Ennos, A.Inst.P., and P. A. Einstein.

An image intensifier is described in which a thin layer of selenium is placed in the electron microscope. The imaging beam causes the selenium to become conducting and potential restoration is provided by an auxiliary scanning beam which produces a television display signal. The device is extremely sensitive and useful images can be obtained with electron microscope beam current densities of the order of 10^{-11} A/cm^2.

British Journal of Applied Physics: Volume 9, No. 12

SPECIAL ARTICLE

The choice of resilient materials for anti-vibration mountings. By J. C. Snowdon.

This article attempts to determine, solely from the aspect of vibration reduction, the criteria which define a good anti-vibration mount material. It concludes that such a material should possess a high damping factor which does not increase greatly with frequency, and that it should be free from any major increase in dynamic modulus with frequency.

Results of transmissibility measurements on a variety of resilient materials indicate that high damping synthetic rubbers normally possess a dynamic modulus which increases rapidly with frequency. It is shown that this modulus increase is responsible for the poor isolation afforded by these rubbers at frequencies above the resonant frequency of the mounting system, and not their inherent high damping as commonly supposed.

Filled butyl rubber is an exception, affording an isolation at high frequencies not greatly inferior to that of natural rubber, yet at the same time possessing much higher damping.

The performance of spark guards. By J. H. McGuire, A.Inst.P., and Margaret Law.

The probabilities that various sizes of live coal will ignite various domestic materials have been determined. In addition the maximum probability that a coal will pass through a mesh has been calculated. Combining the two results has given a measure of the efficiency of spark guards in reducing fire risk. It is suggested that non-flammable Nylon net is a suitable material for a combined fire and spark guard.

Electrical properties of chalcopyrite. By B. Donovan, F.Inst.P., and G. Reichenbaum, Grad.Inst.P.

The conductivity σ and thermoelectric power φ of synthetic and natural specimens of chalcopyrite have been investigated in the temperature range —140 to 300°C. The Hall coefficient R of the natural specimens has also been measured in this region, but in the case of the synthetic specimens is too small to be detected. For the majority of the specimens the product $R\sigma$ varies approximately as $T^{0.7}$ from about 100 to —140°C. This is taken to indicate that impurity scattering of the carriers is predominant, and on this basis the effective mass is estimated to be roughly equal to the free electron mass. The low mobility values encountered suggest that the samples are markedly inhomogeneous and this is further borne out by the decrease in the measured resistance at high frequencies.

A generalized theory of sedimentation. By A. D. Maude, A.Inst.P., and R. L. Whitmore, A.Inst.P.

A theoretical relationship between the concentration and the sedimentation velocity of non-flocculated suspensions of particles is derived. It is shown that the settling velocity relative to that of a single particle in the suspension is $(1 - c)^{\beta}$ where β is a function of particle shape, size distribution and Reynolds number and c is the volume of solid per unit volume of suspension. The expression is shown to satisfy the experimental results of other workers. An empirical relationship between β and the Reynolds' number is suggested.

Resistance bias characteristic of the electron microscope gun. By M. E. Haine, F.Inst.P., P. A. Einstein and P. H. Borcherds.

It has been shown in a previous paper that the theoretical value of current density per unit solid angle (brightness) could be obtained from the hairpin cathode electron microscope gun for a wide range of geometrical design, provided an optimum bias voltage, which depended on the geometrical design, was applied between shield and cathode. When using a self-biasing arrangement, the total beam current tends to become stabilized by negative feed-back action. This is a valuable advantage but may lead to the impossibility of operating the gun at the optimum

bias voltage. The present investigation shows that for a reasonably wide range of geometrical design, conditions can be established, with the correct choice of bias resistance, whereby the gun can be operated at theoretical brightness and with current stabilization, for a reasonable choice of filament temperature, giving a range for choice in beam angle or beam current.

The friction of mineral particles. By R. T. Spurr.

The coefficient of friction of loose particles slid between parallel plates is approximately proportional to the Mohs hardness of the particles. The particles are crushed during sliding.

The magnetic stabilization of low pressure d.c. arcs. By H. Wroe.

Self-sustaining d.c. arc discharges between solid metal electrodes at pressures down to 10^{-4} mm of mercury have been investigated. At pressures below a few millimetres of mercury, arcs on both refractory and non-refractory metals behaved like " cold cathode " arcs. " Spot-splitting " and " reverse driving " of the cathode spot were observed and a form of instability is described. Reverse driving of the cathode spot or spots by the magnetic field set up by the current in the electrodes themselves is suggested as the cause of the instability.

A magnetic method of stabilizing the discharge is described, requiring an axial magnetic field of at least 500 G. A marked constriction of the positive column was caused with this value of field.

The magnetically stabilized discharge has been used experimentally to produce short welds on $\frac{1}{8}$ in. thick mild steel plate at 1 μ of mercury pressure using about 40 A at 30 V.

The grid emitting properties of titanium. By J. A. Champion, A.Inst.P.

Experiments are described in which the emission from thin films of barium and barium oxide deposited on titanium is compared with that from similar deposits on tungsten. With deposits of both barium and barium oxide the emission from titanium is very much less than that from tungsten throughout the temperature range investigated (700-1000° C). Above about 900° C the evaporation of titanium will poison the emission of an adjacent oxide cathode, but it is concluded that from 700° C up to this temperature titanium would possess good grid emission suppression properties. This could enable titanium to be used as a screen grid winding wire in the place of carbonized molybdenum wire in a number of receiving valves, and as an electrode material in other electronic devices where hot electrodes become contaminated with cathode material.

The influence of the method of demagnetization on the reversible permeability of a high-permeability nickel-iron alloy. By R. C. Jackson, E. W. Lee and A. G. H. Troughton.

Measurement of the reversible permeability of a high-permeability nickel-iron alloy shows that its dependence upon biasing field depends upon the method of demagnetization used. Results are found to be partially explicable in terms of residual magnetization, some specimens possessing residual magnetization even after a high-temperature anneal.

ENGINEERS AND PHYSICISTS

Well qualified graduates are invited to apply for appointments to our Research Staff for work in the following fields :—

(1) Electrical insulation in service
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Posts (1) are at Leatherhead, Posts (2) at Perivale, Middlesex. Working conditions are liberal, with opportunities for publication. Initial salaries offered will be within the range £700 to £1,100 p.a. Candidates with Ph.D. or some research experience preferred, but recent graduates will be considered. Applications to The Secretary, Electrical Research Association, Cleeve Road, Leatherhead, Surrey.

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Applications are invited for an Assistant Lecturer, Grade B, in Telecommunications and Electronics. Candidates should have a degree in Physics or Electrical Engineering. A special knowledge or industrial experience of some branch of the subjects would be an advantage.

The salary will be in accordance with the current Burnham Technical Scale, i.e. £650 × £25–£1,025 p.a. plus allowances for degree and training.

Forms of application (together with further particulars) may be obtained from the Principal, Welsh College of Advanced Technology, Cathays Park, Cardiff, to whom they should be returned as soon as possible. Robert E. Presswood, Clerk to the Governors, City Hall, Cardiff.

Applications are invited from holders of a good honours degree in physics, chemistry or chemical engineering, to do research on the ignition of acetylene, for a higher degree. Bursary of £400 p.a. with fees paid. Apply, with details of qualifications, to Dr. J. H. Burgoyne, Department of Chemical Engineering, Imperial College of Science and Technology, London, S.W.7.

METALLURGIST or PHYSICIST GRADUATE required for research program on the electron optical examination of thin metal foils. The work requires a knowledge of electron microscopy and electron diffraction, but training would be given to an otherwise suitable applicant not possessing these qualifications. Pleasant working surroundings. Five day week. Pension Scheme. Apply Aeon Laboratories, Beech Hill, Ridgemead Road, Englefield Green, Egham, Surrey.

BICC

PHYSICIST or ELECTRICAL ENGINEER, graduate preferably of honours degree standard required for the Shepherds Bush research laboratories of British Insulated Callender's Cables Limited. The work involves research and development on dielectrics and capacitors. Previous experience in this field would be desirable but is not essential. Five-day week ; pension fund.

Applications giving details of age, qualifications and experience to be made to Personnel Officer, B.I.C.C. Ltd., 38 Wood Lane, London, W.12.

THE DESIGN OF PHYSICS RESEARCH LABORATORIES

To be published in January, 1959,
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See page 309 of this issue of the "Bulletin"

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47 Belgrave Square, London, S.W.1.

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Address .....
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Date..... Signed.....

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AND
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UNITED KINGDOM ATOMIC ENERGY AUTHORITY
(RESEARCH GROUP)

SENIOR PHYSICISTS at the Radiochemical Centre, Amersham. A senior physicist is required to take charge of the Physics Department. The centre is engaged in the production and distribution of radioactive isotopes on a large scale and the physics department provides essential services including health physics control for the whole establishment, the maintenance of radioactive standards and the calibration of radiation sources, and the design and provision of specialized electronic equipment.

This post calls for a physicist with first-class professional qualifications, substantial experience of work with radio-isotopes for ionizing radiations and the organizational ability to manage a department. The starting salary will be in the range £2,200–£2,600. Normal conditions of service of the U.K.A.E.A. will apply, including membership of a superannuation scheme. A house may be available.

The Group Recruitment Officer (1267/110), A.E.R.E. Harwell, Didcot, Berks, will supply further details of the appointment.

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"THE EDUCATION OF PHYSICISTS IN UNIVERSITIES AND COLLEGES OF TECHNOLOGY"

Being the proceedings of a Conference on

"DEGREE AND DIPLOMA COURSES IN APPLIED PHYSICS"

organized jointly by the Institute of Physics and the London and Home Counties Regional Advisory Council for Higher Technological Education.

The booklet contains papers by :—

SIR JOHN COCKCROFT, PROF. P. M. S. BLACKETT, MR. R. E. BURNETT, PROF. H. LIPSON, DR. J. THOMSON, PROF. M. R. GAVIN, DR. J. TOPPING

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